## REMARKS

Claims 19, 21-27, 30-32, 38, 41, 43, 44, 47-49, and 52-65 are currently pending. Claims 30-32 and 60 have been withdrawn. Claim 51 has been canceled. Claims 19, 38, 43, and 44 have been amended to recite at least three layers or sub-layers and are supported by original claim 41 and page 8, lines 13-18, of the application as filed and to include the subject matter of canceled claim 51. Claims 62-65 have been added to enhance the scope of patent coverage and are supported by the original claims and page 11, line 18, through page 12, line 13, of the specification as filed. It is respectfully submitted that no new matter has been added.

The Patent Office rejected claims 19, 26, 38, 41, 42, 44, 47, 49, 52, 53, 58, 59, and 61 under 35 U.S.C. 102(b) as being clearly anticipated by Hegde, U.S. Patent No. 6,136,682.

**Applicant notes that each of the independent claims 19, 38, 41, 43, and 44 recites a diffusion barrier formed of three or more layers or sub-layers, subject matter previously recited in claims 41 and 51.**

Hegde does not disclose or suggest this arrangement.

The Patent Office has asserted on page 8, lines 6-11, of the Office Action dated May 17 2007, as follows:

> To further clarify the disclosure of three or more sub-layers, and the plurality of sub-layers are between three and ten in number, Hegde discloses "a composite or amorphous barrier layer," "a composite barrier layer," "a barrier layer," "an amorphous barrier material," and a "tantalum silicon nitride material but can be any other amorphous barrier material," and it is well settled that the term "a" or "an" ordinarily means "one or more."

The claims of Hegde's patent refer to a silicon-containing layer, a base layer, or a substrate, upon which is disposed a composite barrier layer comprising a titanium nitride layer in direct contact with a tantalum nitride layer or a first amorphous barrier layer upon which is formed a second amorphous barrier layer, and upon which is formed a copper-containing layer or metallic layer (see claims 1, 9, and 16).

The figures of Hegde only show a two layer arrangement of an interconnect: layers 12/14 of Figure 3; layers 106/108 of Figures 4-10; and layers 120/122 of Figures 9 and 10. Figures 8-10 show the steps of a dual inlaid "damascene" processing in that a first interconnect 106/108 is deposited, a conductor 110 is deposited on the first interconnect, and a second interconnect 120/122 is deposited on the conductor.

Similarly, Hegde discloses, in column 3, lines 13-23, as follows:

> Referring to FIGS. 1 and 2, a 400 angstrom total thickness TaN/TiN layer completely suppressed copper diffusion at excessive temperatures, whereas the prior art FIGS. 1 and 2 clearly illustrate that 400 angstroms of titanium nitride and tantalum nitride alone could not achieve these results. Therefore, there is an unexpected benefit to the TaN/TiN combination, since neither 400 angstroms of tantalum nitride nor 400 angstroms of titanium nitride used in isolation obtain the same benefit as a composite stack of tantalum nitride and titanium nitride at a same thickness.

Hegde discloses, in column 3, line 63, through column 4, line 1, as follows:

> The barrier layer is located at depths from 0 angstrom to 400 angstrom, where 0-200 angstroms defines the titanium nitride amorphous barrier region and 200-400 angstroms defines the amorphous seed layer, which is preferably a tantalum nitride layer or a tantalum silicon nitride layer.

The disclosure of Hegde only teaches a two layer diffusion barrier.

Hegde does not appear to disclose or suggest anything other than a two layer interconnect to form a barrier that "separates the metallic interconnect (e.g., copper) from the silicon-containing region, prohibiting diffusion of copper" (e.g., column 4, lines 17-19).

**In fact, Hegde teaches away from any arrangement other than a two layer diffusion barrier.**

As to a one layer diffusion barrier, Hegde discloses (column 1, lines 41-43) as follows: "Titanium nitride used in isolation has been proposed for use as a copper barrier layer. However, titanium nitride by itself has poor adhesion to copper."

Hegde further discloses at column 1, lines 26-32, as follows:

> One copper barrier layer which has been proposed for use in the integrated circuit industry is a titanium/titanium nitride/titanium (Ti/TiN/Ti) barrier. A problem with this composite barrier layer is that step coverage of titanium is not adequate for integrated circuit processing and does not obtain high yields. In addition, **the titanium/titanium nitride/titanium process requires three different deposition steps**.

Hegde considers the above three layer barrier to be undesirable as evidenced by column 1, lines 38-39, when he remarks "an alternative barrier to the titanium/titanium nitride/titanium barrier is desired in the industry."

Since Hegde finds the above three layer barrier undesirable as requiring extra different deposition steps, Hegde would find a four or more layer barrier undesirable.

Accordingly, Hegde does not anticipate claims 19, 26, 38, 41, 42, 44, 47, 49, 52, 53, 58, 59, or 61.

The Patent Office further asserted on page 9, lines 3-5, of the Office Action dated May 17 2007 as follows:

In the alternative, claims 19, 26, 38, 41, 42, 44, 47, 49, 52, 53, 58, 59, and 61 are rejected under 35 U.S.C. 103(a) as being unpatentable over Hegde.

For the reasoning provided above, claims 19, 26, 38, 41, 42, 44, 47, 49, 52, 53, 58, 59, and 61 are allowable over Hegde.

Additionally, at col. 3 Hegde et al. cite experiments and assert that there is an <u>unexpected benefit of a 400 angstrom composite</u> of TiN and TaN. In contrast, Applicants claim a thickness between about 30 and about 50 angstroms (see, e.g., claim 1), which is significantly less than that of Hegde et al.

Applicants respectfully assert that unexpected results are present as a result of the claimed invention. For example, in contrast to Hegde et al. and as disclosed in the specification at page 4, Applicants have determined how to form a very thin, multilayer diffusion barrier composed of even thinner sub-layers, where the sub-layers are only a few atoms thick. A strong bond between each of the sub-layers perturbs the regular

crystalline structure of the sub-layer, as long as the sub-layer remains very thin. Since the surface energies dominate the bulk binding energies, the sub-layer remains disordered and essentially free of a regular crystalline structure. The lack of formation of a lattice within each sub-layer results in no grain boundary formation, and hence, no pathways for inter diffusion through the barrier.

Hegde et al. do not disclose or suggest such a barrier including, for example, each sub-layer having a specific thickness between about 0.4 and about 4.5 angstroms, wherein formation of crystalline lattice and diffusion of a chemical species through the barrier is inhibited. Hegde et al. particularly teach that "unexpected results" are obtained with a 400 angstrom composite. There is no description in Hegde et al. of the claimed structure at the claimed nanometer scale.

Nor does this reference disclose or suggest the claimed multilayer diffusion barrier including the afore-referenced film thickness, wherein the surface adhesion of each interface inhibits the formation of a lattice in the individual film layers inhibiting diffusion across the barrier, or comprising alternating films of at least two different metals wherein work hardening is substantially eliminated. Nor is the particularly claimed multilayer structure of the claimed thickness disclosed or suggested.

Thus, claims 19, 26, 38, 41, 42, 44, 47, 49, 52, 53, 58, 59, and 61 are allowable over Hegde for this additional reason.

The Patent Office rejected claims 21-25, 27, 43, 48, and 54-57 under 35 U.S.C. 103(a) as being unpatentable over Hegde as applied to claims 19 and 44, and further in combination with Toyoda, U.S. Patent No. 6,001,461.

Hegde teaches away from a diffusion layer of three or more layers, as discussed above.

Toyoda discloses (abstract) an electronic part comprising an amorphous thin film formed on a substrate and a metal wiring formed on the surface of the amorphous thin film where the amorphous thin film provides improved electromigration and stress-migration endurance (column 2, lines 6-8). Toyoda (column 29, lines 39-43) further discloses an amorphous thin film 3 reduces the number of hillocks even when the thickness of the amorphous thin film 3 is 100 Angstroms. The amorphous thin films of

Toyoda are each formed of an alloy two or more metals (column 5, lines 28-61). Toyoda (column 5, line 28, through column 6, line 21) discloses an amorphous thin film that may form an upper layer of a multilayer structure and $SiO_2$, polyimide, TEOS, SiN and the like containing B or P may be used as the underlying layer of the above multi-layer structure. The amorphous thin film may be an aluminum, copper, or cobalt alloy. Toyoda discloses (column 55, line 22, through column 56, line 8) that in Figure 34 a metal wiring 202 may be surrounded by a bottom amorphous thin film 203a and a side and top amorphous then film 203b.

However, Toyoda does not teach or suggest a diffusion layer of three or more layers and so does not cure the deficiency of Hegde.

Thus, claims 21-25, 27, 43, 48, and 54-57 are not made obvious by Hegde in view of Toyoda.

Claim 24 recites "A diffusion barrier as in claim 19, where one of the materials is lanthanum (La)." Although Toyoda in column 4, line 1, recites "lanthanide" as in lanthanide series, Toyoda does not specifically disclose lanthanum.

Claims 54-57 recites sub-layers that are alternately comprised of a first metal and a second metal. Specifically, claim 54 recites copper and tantalum, claim 55 recites scandium and tantalum, claim 56 recites yttrium and tantalum, and claim 57 recites lanthanum and tantalum.

The USPTO admits that Hegde does not disclose or suggest the subject matter of claims 54-57. Additionally, Toyoda, discloses an amorphous thin film of an alloy of two or more metals (column 5, lines 28-61) that may form multi-layer structures with silicon dioxide, polyimide, tetraethoxysilane (TEOS), or silicon nitride containing boron or phosphorus (column 5, line 63, through column 6, line 2) and does not disclose or suggest the claimed arrangements. However, Toyoda, like Hegde, does not teach or suggest sub-layers that are alternately comprised of a first metal and a second metal where the first and second metal layers are copper and tantalum, scandium and tantalum, yttrium and tantalum, or lanthanum and tantalum.

Thus, claims 54-57 are allowable for this additional reason.

New claims 62-65 are dependent from independent claims 19, 38, 41, or 44, and are allowable at least for the reasons discussed above for the allowability of the

independent claims they depend from. The recited subject matter of claims 62-65 further distinguishes from the prior art of record.

In view of the foregoing, it is asserted that there is no teaching or suggestion that would motivate one of ordinary skill in the art to combine and modify the cited references in an attempt to arrive at the subject claims.

All issues having been addressed, the subject patent application is believed to be in condition for immediate allowance. No new issues requiring a further search are presented and thus the Examiner is requested to enter and consider and Amendent. Accordingly, the Examiner is respectfully requested to reconsider and remove the outstanding rejections and objection. An early notification of the allowance is earnestly solicited.

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